Holographic Fourier-synthesis custom-coherence illuminator suitable for 0.5-NA extreme ultraviolet microfield lithography

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Synchrotron radiation is a coherent, debris-free radiation source suitable for extreme ultraviolet (EUV) microfield exposure tools (METs). There are two basic challenges when dealing with coherent light for general imaging applications: achieving uniform illumination and obtaining the desired pupil fill (partial coherence factor). This paper describes a two-stage system meeting both of these criteria that is suitable for use in a 0.5 numerical aperture (NA) EUV MET employing synchrotron radiation.

The first stage of the illuminator is uniformity stage, designed to create a uniform illumination footprint across the entire field from an arbitrary input intensity profile. Shown in Figure 1 (optics 1 and 2) , the uniformity stage is comprised of a square-wave-carrier phase-only EUV holographic optical element (HOE) [1] implemented as a programmed diffuser and a collection optic to redirect the +1 and -1 diffraction orders from the HOE towards the second stage of the illuminator. To eliminate fringes in the far-field overlap region, one branch of the collection optic is offset by the 500-nm illumination coherence length, ensuring that fringes from different spectral elements (colors) are spatially shifted enough to make the net fringe contrast vanish.

The second stage of the illuminator (optics 3 and 4) is a two-axis scanning galvanometer that manipulates the angle that the incoming radiation strikes the object during the exposure [2]. Mutual incoherence of the various angles is ensured through the scanning process by virtue that none of the angles coexisting in time. By varying the illumination angle during the exposure, any desired pupil fill can be achieved. In addition, the scanning mirror is imaged to the object to ensure stationarity of the pupil fill across the field.

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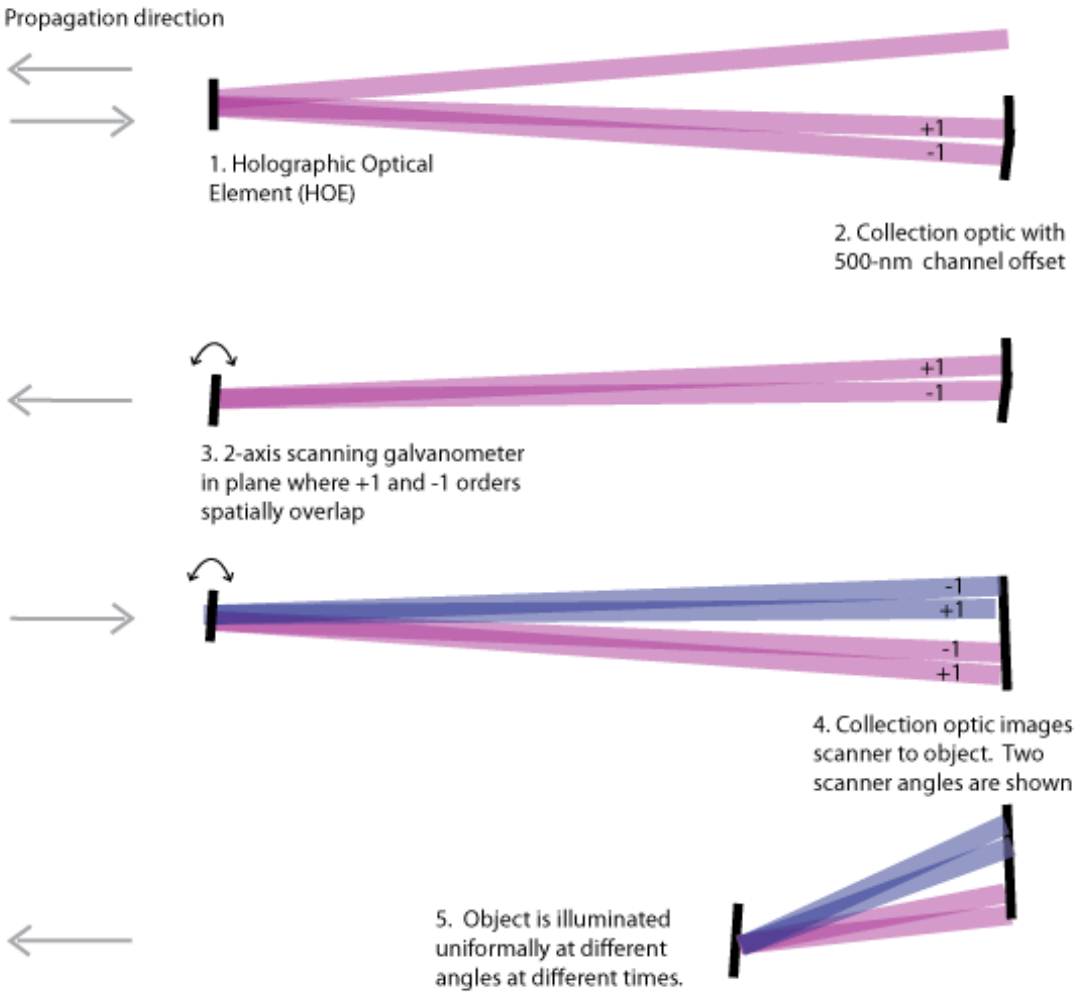

Figure 1: Schematic of two-stage holographic Fourier-synthesis custom coherence illuminator. The system consists of four optical elements. The schematic shows the path between each illuminator optic (labeled #1-4) separately.

References:

[1] P. Naulleau, F. Salmassi, E. Gullikson, A. Liddle "Design and fabrication of a high-efficiency extreme ultraviolet binary phase-only computer-generated hologram," Applied Optics Vol 47, No 17 pp 2581-2585

[2] P. Naulleau, K. Goldberg, P. Batson, J. Bokor, P. Denham, S. Rekawa, "Fourier-synthesis custom-coherence illuminator for extreme ultraviolet microfield lithography" Applied Optics Vol. 42, No. 5 pp 820-826